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CONFERENCING AND TELECONFERENCING IN THREE COMMUNICATION MODES AS A FUNCTION OF THE NUMBER OF CONFEREES

(REPRINT)

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20. ABSTRACT:

Nine groups of 2, 3, and 4 students each, 27 groups in all, discussed topics face-to-face or in one of two teleconference modes: teletype and televoice. Each group used only one of the three communication modes to solve a different problem on each of 3 successive days. Each problem encouraged opinionated discussion and required the group to arrive at a consensus about certain topical issues. Group size had no effect on time to solution or on the solutions themselves, but an increase in group size resulted in an increase in almost every group measure of communication. The larger groups used more messages, more words, communicated faster, and exhibited greater relative variability among the numbers of messages generated by the individuals within groups than did the smaller groups. Equivalent solutions were also reached in all communication modes, but subjects in face-to-face conferences used more messages and words than did subjects in either of the telecommunication modes. Communication rates were much higher and solutions were reached much faster in the two conference modes that had a voice channel, i.e., face-to-face and televoice, than in the teletype mode. Few practice effects were found.

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Conferencing and teleconferencing in three communication modes as a function of the number of conferees

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Nine groups of 2, 3, and 4 students each, 27 groups in all, discussed topics face-to-face or in one of 2 teleconference modes: teletype and televoice. Each group used only one of the 3 communication modes to solve a different problem on each of 3 successive days. Each problem encouraged opinionated discussion and required the group to arrive at a consensus about certain topical issues. Group size had no effect on time to solution or on the solutions themselves, but an increase in group size resulted in an increase in almost every group measure of communication. The larger groups used more messages, more words, communicated faster, and exhibited greater relative variability among the numbers of messages generated by the individuals within groups than did the smaller groups. Equivalent solutions were also reached in all communication modes, but subjects in face-to-face conferences used more messages and words than did subjects in either of the telecommunication modes. Communication rates were much higher and solutions were reached much faster in the two conference modes that had a voice channel, i.e., face-to-face and televoice, than in the teletype mode. Few practice effects were found.

1. Introduction

Teleconferencing refers to interactive communication among physically separated persons *via* electronic media. Although teleconferencing includes all two-way telephone conversations, the term is more commonly used to refer to communication involving more than two persons. The interactive nature of communication among conferees distinguishes teleconferencing from one-way, or non-interactive forms of communication such as radio and television broadcasts.

A familiar example of teleconferences are centrally-arranged conference telephone calls made for many businesses and government agencies to connect people located in different cities. Not only are these calls speedy and convenient for business transactions among people who may be physically separated, but they also conserve personnel resources, time, and travel costs by substituting for face-to-face meetings.

Teleconferencing is not limited to the telephone medium. A variety of devices, *e.g.* teletypewriters, telewriters (*i.e.* handwriting and drawing transceivers), and television, also allow groups of physically separated persons to communicate interactively. All have been tried experimentally in a wide variety of business and commercial settings (Johansen *et al.* 1979), and have been used in conference applications such as telemedicine (Bashshur *et al.* 1975, National Aeronautics and Space Administration 1974) and telebanking (Casey-Stahmer and Havron 1973).

Not all teleconference systems have been successful, and we have gradually come to realize that the ultimate widespread acceptance of all teleconferencing systems depends on a number of considerations, ranging from the design of hardware components to the users' perceptions of the effectiveness of both the system and the conference (Short *et al.* 1976).

For about the past nine years, a programme of laboratory research at The Johns Hopkins University has been systematically investigating some of the psychological variables associated with interactive person-to-person communication mediated through various electronic channels. The purpose of these studies has been to discover

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(1) how people normally communicate with one another, (2) how their communications are affected by the machine devices or electronic media through which they communicate when they are physically separated, and (3) the effects of some human and system variables on interactive communication. Summaries of the major findings of that work appear in Chapanis (1975, 1976). The study reported here is another in the Hopkins programme.

2. Purpose

This experiment studied groups of 2, 3, and 4 conferees as they communicated in one of three modes to arrive at consensus solutions to realistic group decision-making problems. The purpose of the research was to find out how group communication changes as a function of (1) the number of conferees, (2) the mode of communication, and (3) successive days of test.

Three modes of communication were tested: teletype, televoice and face-to-face. The face-to-face meetings provided baseline data for evaluating performance in the two mediated modes of communication. The teletype and televoice modes are representative of teleconferencing channels that are readily available and are relatively inexpensive. In the teletype mode conferees could neither see nor talk to each other, but they had a printed version of all transactions that could be referred to any time. In the televoice mode, a close analogue to 'hands-free' telephoning, conferees could not see each other but had the speed, flexibility and full range of expression that can be conveyed by voice. In all three modes the network arrangement was such that whenever one conferee communicated, the others in the net simultaneously received the message.

3. Method

3.1. *Subjects*

The subjects were 81 undergraduate male students at The Johns Hopkins University. They were paid an hourly wage for each session, a bonus for completion of all three experimental sessions, and a share of a second bonus based on the 'correctness' of their group's solution to each of three problems.

3.2. *Communication modes*

The term communication *mode* refers to a particular combination of methods and devices used to exchange information.

3.2.1. *Teletype mode* (*TTY*). In the teletype mode each subject was in an individual room equipped with a teletypewriter. The subjects held their conference by typing messages to one another. Messages by all subjects were typed on a continuous roll of paper on every machine and so were continuously available for reference.

3.2.2. *Televoice mode* (*TELEV*). In the televoice mode each subject was in an individual room and was able to communicate with the other members of his group only over a microphone and speaker system. When any subject spoke, his voice was simultaneously transmitted to all the other members of the group. This situation resembled an ordinary conference telephone call except that subjects did not have to hold a telephone handset.

3.2.3. *Face-to-face mode* (*FTF*). In this mode, subjects conducted their conferences sitting around a rectangular table. In the 2-person groups, subjects sat across the table

from each other; in the 3- and 4-person groups, each subject sat at one side of the table. The subjects were able to see and hear one another in an unobstructed manner.

3.2.4. *Interrupt capability in the several modes.* One important difference between the teletype mode and the other two modes concerns the freedom of a 'speaker' to interrupt. In the modes that allowed spoken communication, interruptions were easily made by 'speaking up,' and even though he may have been interrupted, a speaker could continue to speak until he had completed his message or until he decided to stop talking. The latter behaviour resulted in frequent episodes of overlapping or simultaneous speech by two or more conferees.

On the other hand, subjects who communicated via teletypewriter had to follow a somewhat more rigid set of rules for interruptions (see Apparatus). Overlapping or simultaneous messages were impossible.

3.3. *Apparatus*

3.3.1. *Laboratory rooms.* Four adjacent laboratory rooms, each 3·2 × 4·1 m. in size, were used for tests in the teletype and televoice modes. A conference room 4·6 × 7·6 m. in size was used for tests in the face-to-face mode.

3.3.2. *Teletype equipment.* Each subject in the teletype mode had one teletype machine (*Teletype, Model 33 KSR*) that he used both to send and to receive messages. The teletype machines were slaved together electrically in a half-duplex broadcast conference network. When any subject typed a message on his machine, it was simultaneously typed out, character-by-character, on the other machines in the net.

Messages could be transmitted in only one direction at a time. By depressing a circuit control button, any subject could take immediate control of the communication channel and cut off abruptly a message being typed. He retained control of the channel until another subject took it by depressing his control button. A subject who had been interrupted found his keyboard inoperative, and could only regain control of the channel by pushing his own control button. Contests for control of the channel were infrequent. A small red light was illuminated on the console that had control of the teletype circuit. All messages were automatically marked with the sender's identification code in the left margin.

3.3.3. *Televoice equipment.* The televoice equipment consisted of four desk mounted, uni-directional microphones (*Sony, Model ECM-200S*) whose signals were mixed into a 10-watt amplifier (*Bogen, Model CHB-10A*) that in turn drove four wall-mounted loudspeakers (*Lafayette, Model F-45494*).

3.3.4. *Face-to-face equipment.* Uni-directional microphones on the table (1·83 m × 2·44 m) in front of each participant were used for recording conversations. Each fed a single channel of a 4-channel audio tape recorder (*Sony, Model TC-277-4*).

3.4. *Problem solving tasks*

The three problem solving tasks were designed to be of topical interest to students. Moreover, the basic nature of the task did not change when it was used with either 2, 3 or 4 conferees. Although the problems were cooperative in the sense that subjects on a team pooled their collective opinions to reach solutions, the problems usually elicited a considerable amount of persuasive and argumentative discourse.

3.4.1. *National issues problem.* The national issues ranking problem, developed by Weeks and Chapanis (1976), consisted of ten economic, environmental, political and social issues of national concern. They are listed below in the order in which they were given to each subject:

(i) Provision of equal opportunity in education.
(ii) Achievement of a stable peace in the Middle East.
(iii) Control of inflation.
(iv) Finding a truly effective treatment for drug addiction.
(v) Development of alternative energy resources.
(vi) Allocation of highway funds to mass transit.
(vii) Restoration of confidence in the political system.
(viii) Reform of the judicial and penal system.
(ix) Achievement of zero population growth.
(x) Increased consumer protection through legislation.

The problem was administered in two parts. In the first part, each subject was asked to rank the issues in the order that he himself would direct attention to them if he could "re-order the national priorities." He was told that his ordering would not be disclosed to the other subject(s) by the experimenter and would not be used in the subsequent conference.

In the second part, the group of subjects was told that the list of ten issues had been previously ranked by a large number of undergraduates. The group's task was to work together to rank the issues not as they would privately, but rather as they thought the average undergraduate had ranked them. The group was also told that each member could earn a bonus of up to $3·00 in addition to their hourly pay, the amount of the bonus to be proportional to the correlation between their jointly agreed upon ranking and the ranking found in the student survey. The mean bonus payment for each session was $1·94 with a range of $1·68 to $2·13.

3.4.2. *University budget problem.* In this task subjects were asked to rank order ten administrative, academic and economic changes that might help bring the University's budget into balance. The order listed below is that given the students:

(i) Delay construction of new buildings and renovation of old ones.
(ii) Cut the plant operating expenses (heating, air conditioning, grounds upkeep).
(iii) Cut the M.S.E. Library operating budget.
(iv) Freeze pay raises for the faculty.
(v) Freeze the hiring of new instructor personnel.
(vi) Cut the size of the administrative staff and services.
(vii) Raise the student tuition and fees.
(viii) Decrease financial aid to students.
(ix) Institute a tri-semester system at the University.
(x) Eliminate the intersession.

Each subject was asked to imagine that his fellow students had selected him to represent them on an *ad hoc* committee to make recommendations to the University administration about these financial matters. He was first asked to rank the measures in the order that he would recommend them to the Administration. The procedure for the conference part of this problem was identical to that used with the national issues problem, that is, subjects as a group were to determine how the average undergraduate ranked them in a student survey.

3.4.3. *Student activities budget problem.* The discussion material for this task consisted of ten student activities for which funding priorities had to be determined. The activities are listed below in the order in which they were given to the students:

(i) MaryPIRG (consumer oriented Maryland Public Interest Research Group).
(ii) Band (student concert and marching band).
(iii) Course Guide (publication of opinions on courses offered and on the professors who teach them).
(iv) Hullabaloo (the University's student yearbook).
(v) News-letter (student newspaper).
(vi) M.S.E. Symposium (student run event with nationally known speakers).
(vii) Student Council (student governmental body).
(viii) Undergraduate Science Bulletin (student research publication).
(ix) Women's Centre (female student discussion forum).
(x) Barnstormers (student drama and theatre group).

The explanatory remarks in parentheses did not appear on the materials given to the students.

Each subject was asked to imagine that he had been appointed to a committee responsible for deciding the order in which funds should be allocated to these ten student activities. The procedure for the two parts of this problem was identical to that used with the other two problems.

Table 1. Experimental Design.

Group Size	Communication Modes	Groups	Day 1	Day 2	Day 3
2-Man	TTY	G 1	P 1	P 3	P 2
		G 2	P 3	P 2	P 1
		G 3	P 2	P 1	P 3
	TELEV	G 4			
		G 5	"	"	"
		G 6			
	FTF	G 7			
		G 8	"	"	"
		G 9			
3-Man	TTY	G 10			
		G 11	"	"	"
		G 12			
	TELEV	G 13			
		G 14	"	"	"
		G 15			
	FTF	G 16			
		G 17	"	"	"
		G 18			
4-Man	TTY	G 19			
		G 20	"	"	"
		G 21			
	TELEV	G 22			
		G 23	"	"	"
		G 24			
	FTF	G 25			
		G 26	"	"	"
		G 27			

P 1 = National Issues Problem
P 2 = University Budget Problem
P 3 = Student Activities Budget Problem

TTY = Teletype Mode
TELEV = Televoice Mode
FTF = Face-to-face Mode

3.5. *Experimental design*

The experimental design (table 1) was a mixed one with two between-groups variables (group size and communication modes) and two within-groups variables (days and problems). The order of presentation of the problems was balanced across days in a latin square format that was replicated across communication modes and group sizes.

3.6. *Procedure*

Each subject was scheduled with one or more others to form a group of 2, 3 or 4 conferees. Subjects who admitted either to being close friends or to socializing together were assigned to different groups. Subjects remained in the same group on all three days. Groups were assigned to experimental conditions at random.

Before starting, the experimenter read the subjects a set of instructions stating that the purpose of the experiment was to study communication, that they could use any problem-solving strategy they felt was appropriate, and that they could do or say anything during their conferences that would help their group reach a solution. The subjects were also told that audio tape recordings, teletype printouts, observer notes and other records would be collected during the sessions. They were told that the records would be kept confidential and would be used only for data analysis and research purposes. Written permission to collect these records was obtained from the subjects.

4. Data collection and analysis

Four kinds of data were collected: (1) time to solve the problem, (2) measures of verbal productivity, (3) each subject's own rankings and the rankings agreed on by the group for the items in each problem, and (4) responses to a questionnaire which sampled each subject's opinions about the communication mode he had used.

4.1. *Time to solution*

Time to solution was the time that elapsed from the moment the experimenter told the group to begin until one of the conferees told the experimenter that the group had reached a consensus.

4.2. *Measures of verbal productivity*

In the teletype mode subjects generated hard-copy printouts of their verbal exchanges. In the two oral modes, messages spoken by each person were recorded on audio tape and were subsequently transcribed to typewritten protocols. Great care was taken to capture faithfully the many rapid and complex verbal exchanges that took place. The rules of transcription were those formulated by Chapanis *et al.* (1972, 1977) and Weeks and Chapanis (1976). Essentially, they combined the use of conventional English orthography with the preservation of the subjects' natural style of communication. For example, elisions common to American speech, *e.g.*, "gonna," were transcribed as spoken rather than as their constituent words.

4.2.1. *Number of messages.* A message began when a subject began to talk or to type, and ended either when he had finished and relinquished control of the communication channel to his partner(s), or when he stopped talking or typing because he was interrupted. By this definition, a message could be a word, a group of words, a complete

sentence or question, or several sentences or questions. The number of messages is a function of both verbal productivity and the frequency with which subjects exchanged control of the communication channel.

Since two or more conferees could talk simultaneously in the voice modes, messages could overlap. Frequently, the subject who had been speaking first would stop almost immediately upon being interrupted. Ocasionally, however, a subject would continue talking and his partner(s) would superimpose two or more discrete utterances on the one long message of the first subject. Such overlapping messages occurred with each of the three sizes of group, even in the two-man conferences, and resulted in different numbers of messages for each of the conferees.

The numbers of messages exchanged by all conferees in a group were pooled in each session to provide a measure of group performance. The total number of messages divided by the number of conferees in the group yielded a measure of the average number of messages used by each conferee.

4.2.2. *Number of words.* Although counting words is not inherently difficult, establishing rules of what to count is. In a 'hard copy' communication mode, *e.g.* teletype, where the communicators print out their own messages, a word could be defined simply as any string of letters and/or digits surrounded by spaces. However, in making counts from transcripts of spoken communications, such a decision logic is neither very realistic nor practicable. Mispronunciations, elisions and contractions, partially completed words, colloquialisms, interjections and vocal gestures all require a more elaborate set of rules.

On the assumption that most verbal utterances and typewritten sequences of symbols convey some information, our definition of what constituted a word was extremely liberal. The rules used in making the word counts are based on those established in earlier communication experiments in the Hopkins laboratory. The counts for all conferees in a group were pooled to provide a measure of group performance. The total number of words used by a group was divided by the number of conferees in the group to yield a measure of the average number of words used per person.

4.2.3. *Mean message lengths.* The average number of words per message was the total number of words used by a group divided by the number of messages it generated.

4.2.4. *Communication rates.* Two measures of communication rate were computed: (1) the number of messages per minute, *i.e.* the total number of messages used by a group divided by the total time in minutes required to reach a solution, and (2) the number of words per minute, *i.e.* the total number of words used by a group divided by the total time in minutes.

4.2.5. *Relative variabilities among group members in performance.* Coefficients of variation (Peters and Van Voorhis 1940, pp. 78–79) were computed for the numbers of messages and the numbers of words used by the subjects within each group. This coefficient allows one to compare the relative variability, or disparity, among several sets of measures when the sets of measures have been corrected for differences among their means. The formula is: $V = 100\sigma/M$, where V is the coefficient of variation, σ is the standard deviation of a set of measures, and M is the mean of the set of measures.

4.3. *Equivalence of solutions*

Two sets of rankings were collected from the subjects in each session: (1) a pre-conference ranking of each subject's private view on the issues, and (2) the group's consensus about the average undergraduate's ranking of the same 10 items. The initial rankings by all 81 subjects were pooled for each problem and the 10 items for each problem were scaled by the normalized rank method (Guilford 1954, pp. 181–183) to create three sets of criterion rankings. A product-moment correlation was then computed between the appropriate scaled criterion ranking and each group's consensus solution. The 81 resultant r's were transformed to Fisher z's and the latter were analysed by the *analysis of variance*.

Kendall's coefficients of concordance were also computed for the consensus rankings of the three groups of subjects in each of the 27 combinations of group size, mode, and problem. Finally, for each of the same 27 combinations of groups a *Spearman rank-order correlation* was computed between (1) the mean consensus ranking for the three groups and (2) the appropriate criterion ranking. *Friedman two-way analyses of variance by ranks* were used to test the coefficients of concordance and coefficients of correlation separately for possible significances among the different sizes of group, modes, and problems. The analyses described in this paragraph assume that there are no significant effects among days or any interactions involving days, an assumption that seems tenable in the light of evidence to be presented later.

4.4. *Questionnaire data*

The questionnaire solicited opinions about: (1) the communication mode the subject had used, (2) a subject's satisfaction with the size of group in which he had worked, and (3) how the group functioned on successive days. The questions also elicited information about any critical incidents that might have occurred during the several conferences. Because of the open-ended nature of the questions, and the qualitative nature of the responses, the questionnaire data do not lend themselves to complex statistical treatment. Responses were simply sorted into a few broad categories and frequency counts were made of the numbers of responses in those categories.

5. Results and discussion

The *analyses of variance* on all the quantifiable dependent measures yielded 18 significant main effects (Table 2). Twelve were for the two main variables of Group Size and Communication Mode. At the same time only one of the nine interactions between these two variables was statistically significant. This means that while Group Size and Communication Mode appear to be highly important variables in determining performance in this experiment, these two variables are almost entirely independent of one another. Moreover, the effects of Group Size and Communication Mode are robust, that is, they largely hold for all three Problems and for all three Days of test. There were only three significant interactions among the 54 involving Problems and Days.

Three significant effects attributable to successive Days of test indicate that there were some changes in group performance over time. However, the very few significant interactions involving Days (2 out of 27) and the nature of those interactions (discussed later), suggests that whatever changes occur over time are largely independent of the other main variables.

Table 2. p Values of All Statistically Significant Effects Identified by the Analyses of Variance for the 9 Dependent Variables.

	Between Groups			Within Groups							
Dependent Variables	Group Size (GS)	Modes (M)	(GS × M	Days (D)	Problems (P)	GS × D	GS × P	M × D	M × P	GS × M × D	GS × M × P
Time to Solution		0·005									
Verbal Measures											
Number of Messages per Group	0·005	0·001									
Number of Words per Group	0·025	0·001		0·050		0·025					0·005
Mean Message Length	0·050			0·025	0·025			0·050			
Messages per Minute	0·001	0·001	0·025		0·025						
Words per Minute	0·005	0·001									
Relative Variability Among Numbers of Messages	0·001	0·005		0·025							
Relative Variability Among Numbers of Words											
Accuracy of Solution					0·005						

Note: The p values are those of the upper limits of the intervals: $p<0{\cdot}001$, $0{\cdot}001<p<0{\cdot}005$, $0{\cdot}010<p<0{\cdot}025$, $0{\cdot}025<p<0{\cdot}050$.

5.1. *Time to solution*

The only statistically significant differences in time to solution were those associated with Communication Modes (Tables 2 and 3). On the average, groups conferring by teletype took more than twice as long to arrive at a consensus as did those who conferred by televoice, and over one and one-half times as long as those who met face-to-face. One important feature that distinguishes communication by teletype from the other two modes is that the former does not have a voice channel. Based on earlier work from this laboratory, especially that of Ochsman and Chapanis (1974), the presence or absence of a voice channel is a critical feature in determining time to solution.

Table 3. Means for Statistically Significant Communication Mode Effects

	Communication Mode		
	Face-to-face	Televoice	Teletype
A. Time to solution (min.)	23·6	17·0	36·1
B. Verbal measures			
Messages per group	413·2	269·1	82·1
Words per group	4275·7	2914·6	725·5
Communication rate: Messages per minute	16·9	15·4	2·4
Communication rate: Words per minute	174·6	166·4	19·7
Relative variability among messages	18·4	13·6	10·4

The orthogonal comparison between groups that worked in the teletype mode and those that conferred in the other two modes (teletype *vs.* face-to-face + televoice), was highly significant ($0{\cdot}001 < p < 0{\cdot}005$) and accounted for 88·5% of the variance among modes. Although the other orthogonal comparison, face-to-face *vs.* televoice, was not significant, solutions in the televoice mode were nearly 40% faster than in the face-to-face mode. Gestures and body language do not appear to contribute to efficient problem solutions, at least for problems of this type. The findings here, and especially the lack of a significant interaction between Group Size and Modes, show that the effects previously reported for two-man groups (Chapanis *et al.* 1972, Chapanis and Overbey 1974, Ochsman and Chapanis 1974, Weeks and Chapanis 1976) hold for 3- and 4-person groups as well.

Also of interest is the complete absence of any other significant effects for solution times. Contrary to what we had expected from the literature, increasing the size of the conference group did not significantly change the time it took groups to reach consensus agreements. Nor did working together on three similar problems on three successive days result in faster or slower solution times even when groups were allowed to use the same communication mode throughout.

The problems in this experiment were designed to be similar to one another. The data show that they were similar at least in the amount of time taken for their solution.

5.2. *Verbal measures*

5.2.1. *Effects of group size.* The size of the conference group had a significant effect on six measures of verbal communication (Tables 2 and 4). The two principal measures of verbal productivity, the numbers of messages and of words, increased regularly as the number of conferees increased. In both cases, trend analysis shows significant linear trends and no evidence of significant curvilinearity. When productivity is measured in

Table 4. Means for Statistically Significant Group Size Effects

	Group Size		
	2-man	3-man	4-man
Number of messages	144·6	258·6	361·3
Number of words	1736·4	2482·2	3697·3
Message length	12·1	9·3	9·8
Communication rate: Messages per minute	8·2	12·1	14·3
Communication rate: Words per minute	99·2	115·1	146·4
Relative variability among messages	2·5	18·2	21·9

terms of the average productivity per person, differences attributable to group size are no longer significant. Each addition of another conferee to the group resulted in a relatively constant increase in the number of messages (between 70 and 90) and of words (between 825 and 925). These figures on the average verbal productivity per person should not be taken too literally. The communicative output was not shared equally among conferees, that is, some conferees talked more than did others (See the section on *Relative variability among messages*).

There were no significant interactions of Group Size (GS) with Modes (M) or Problems (P) for either the number of messages or number of words. This means that the differences in verbal output for the three different sizes of group hold for all three communication modes and for all three problems. The two significant interactions involving group size, GS × D and GS × M × P, discussed later, do not really alter the general conclusions about the strong effects of group size on verbal output.

(1) *Message lengths.* Although Table 4 shows a nearly linear increase in both the numbers of messages and of words as a function of group size, the two sets of data are not exactly proportional. As a result, dividing the one measure by the other to get a measure of words per message, or message length, reveals some small, but statistically significant differences (Table 4). Messages in the two-person groups were about 25 per cent longer, on the average, than in the larger groups. The difference between the message lengths for the 3- and 4-person groups is small and not statistically significant. Since there are no significant interactions involving Group Size, the findings about message lengths for the three sizes of group held for all three Communication Modes, Problems, and Days and for all combinations of Modes, Problems and Days tested in this study.

One explanation for the longer messages in the 2-person conferences is that there were fewer interruptions and fewer simultaneous conversations in those conferences. There were 624, 1444, and 2839 occurrences of simultaneous speech for the 2-, 3- and 4-person groups respectively in the two voice modes. The total number of messages for the same groups were 3352, 6323, and 8748. In a two-person conference, one person was perhaps less likely to interrupt his partner since such an interruption would decrease the chance that either person would comprehend what was going on. In 3- and 4-person conferences, on the other hand, if a conferee began to speak while some other person was already speaking, there was at least a chance that a third or fourth member of the group would shift his attention to the new speaker. Our data thus confirm what Kite and Vitz (1966) had observed informally without quantification.

(2) *Communication rates.* As already noted, times to solution did not differ for the 2-, 3- and 4-person groups, but numbers of messages and of words did. It follows that communication rates, measured either in messages per minute or words per minute, should vary as a function of group size. Table 4 shows that both communication rates increased regularly, and in an almost linear fashion, as group size increased. Moreover, there was only one significant interaction involving group size (Figure 1).

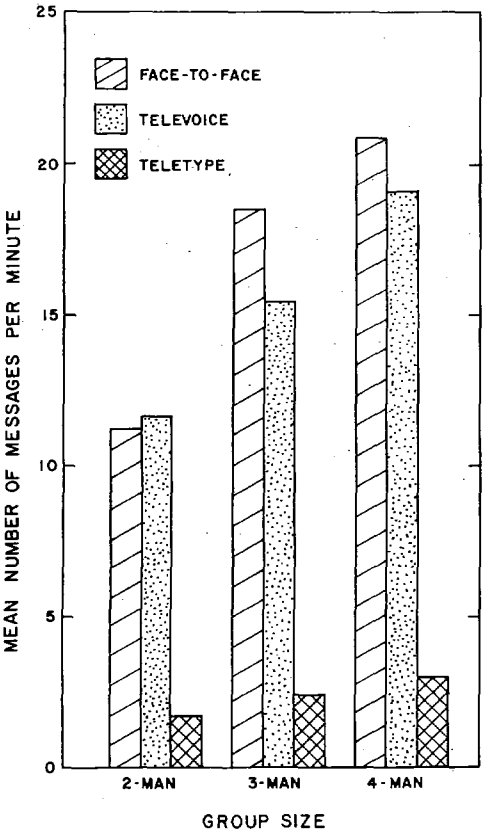

Figure 1. Mean communication rates (messages/minute) as a function of group size and communication mode.

These findings do not necessarily mean that subjects in larger groups talked or typed faster than did those in smaller groups. The communication rates used here are not pure measures of communication rate, that is, the numbers of messages, or of words, per minute spent communicating. They are rather numbers of messages for groups, or of words for groups, divided by the total solution time. In other words, our measure includes intervals when nothing was being communicated. If there are fewer or shorter silent intervals in larger conferences than in smaller ones, communication rates, as we measured them here, should increase as group size increases. Additionally, messages tend to be shorter in the 3- and 4-person groups than in the 2-person groups. If messages are shorter and total time is constant, then messages per minute could increase. These two explanations would account for the increase in the number of messages per minute even in the teletype mode where it is impossible for two or more conferees to communicate at the same time (See Figure 1).

Figure 1 also shows that in the 2-man groups, communication rates are about equal in the face-to-face and televoice modes. For the 3- and 4-man groups, however, communication rates in the face-to-face mode were substantially greater than in the televoice mode. In a 2-person group, simultaneous speaking represents a direct and obvious interference with the only other person in the conversation. In a 3- or 4-person group, however, two people may address remarks simultaneously to a third or fourth silent partner. That kind of simultaneous conversation is more likely to occur in the face-to-face mode where both speakers can direct their speech by turning toward the silent person(s). The data support this interpretation. For the 3- and 4-man groups there were 2850 occurrences of simultaneous speech out of a total of 8918 messages in the face-to-face mode but only 1433 out of a total of 6153 messages in the televoice mode.

(3) *Relative variability among messages.* Coefficients of variation for each group were analysed in the same way as all the other measures. A small mean coefficient indicates that the members of a group produced nearly equal numbers of messages; a large mean coefficient indicates that some members of a group generated disproportionately more messages than did others.

The data show that the members of the two-man groups tended to share almost evenly in the number of messages produced. However, in the larger groups one or more members seemed to dominate by producing relatively more messages, whereas one or more other team-mates tended to produce correspondingly fewer messages (Table 4). This provides some quantitative support for what Kite and Vitz (1966) said they had observed.

The data for the two-man groups should, however, be interpreted with some caution because they were artificially constrained. In the teletype mode, the numbers of messages communicated by the two team members could not differ by more than one. In the face-to-face and televoice modes, the numbers of messages by the two conferees could differ by more than one, but only if one conferee made one or more short utterances while his partner continued talking. In the 3- and 4-man groups, on the other hand, the numbers of messages could differ because of overlapping messages, because one or more members actually communicated less, or both.

5.2.2. *Effects of communication mode.* Communication Mode had a significant effect on five of the seven verbal measures (See Table 3). Groups in the face-to-face mode generated about one and one-half times as many messages per conference as did those in the televoice mode, and about five times as many as those in the teletype mode. Both orthogonal comparisons of interest were significant. The two modes containing a voice channel resulted in significantly more messages than the teletype mode ($p < 0{\cdot}001$, accounting for 81·2% of the variance among modes) and the face-to-face mode resulted in significantly more messages than the televoice mode ($0{\cdot}010 < p < 0{\cdot}025$, accounting for the remaining 18·8% of the variance among modes). Being able to see the person(s) with whom you are conversing increases, rather than decreases verbal output.

These basic findings are much like those reported in earlier studies from this laboratory for two-person groups. The absence of any significant interactions involving modes, however, indicates that the differences among the numbers of messages in the three modes of communication hold for all three Group Sizes, all Problems, all three Days, and all the combinations of these variables that were tested in this study. The latter is a very significant extension of the generality of the earlier findings.

The data for the number of words communicated in the several modes differ by about a factor of 10 from those for the number of messages. Orthogonal comparisons again show the two voice modes to be significantly different from the teletype mode ($p<0{\cdot}001$, accounting for 85·6% of the variance among modes) and the face-to-face mode significantly different from the televoice mode ($0{\cdot}025<p<0{\cdot}05$, accounting for the remaining 14·4% of the variance among modes).

Because of the almost identical proportionality between the data for the number of messages and those for the number of words, mean message lengths did not differ significantly among the several modes of communication.

Table 3 shows that 54% more messages were produced in the face-to-face mode than in the televoice mode. Since these additional messages required about 39% more time, the mean numbers of messages communicated per minute (Table 3) do not differ very much for the two voice modes. Far fewer messages per minute were, of course, transmitted in the teletype mode.

Since the data for the number of words are almost identically proportional to those for number of messages, communication rates expressed in terms of number of words per minute parallel almost perfectly communication rates expressed in messages per minute.

For both measures of communication rate the orthogonal comparison of face-to-face + televoice *vs.* teletype was highly significant ($p<0{\cdot}001$) and accounted for over 99% of the variance among modes. The orthogonal comparison of face-to-face *vs.* televoice was not statistically significant.

Some part of the large difference in communication rates between the hard copy and the two voice modes is, of course, attributable to the simultaneous speech that was possible in the voice modes and not in the teletype mode. A more important part of the difference can be attributed to the fact that irrespective of typing ability people do not type messages on a teletype machine as quickly as they can speak them over a telephone or in a face-to-face conversation, a finding that is well documented by the work conducted in the Chapanis laboratory.

The relative variabilities in Table 3 show that conferees produced much more nearly equal numbers of messages in the teletype mode than in the televoice and face-to-face modes. Only one orthogonal contrast was significant. The two modes containing a voice channel produced more variability among the numbers of messages than did the teletype mode ($0{\cdot}025<p<0{\cdot}05$, accounting for 64·5% of the variance among modes). The comparison between the face-to-face and the voice modes was not significant.

Although the relative variability among numbers of words was not significant, the conferees also produced more nearly equal numbers of words in the teletype mode than in either of the two voice modes.

5.2.3. *Effects of days.* Differences attributable to Days (sessions) were significant for three of the seven verbal measures. The number of messages and the number of words produced per conference decreased regularly from session to session but only the latter effect was statistically significant (mean numbers of words = 3082, 2818, and 2015 for Days 1, 2, and 3, respectively; $0{\cdot}025<p<0{\cdot}05$). As subjects learned to work together, the group as a whole and the subjects individually required fewer words to reach agreement on successive days of test.

There was, however, a significant interaction between Days and Group Size in the numbers of words used by the groups. Although the 2- and 4-man groups both showed

a regular decrease in the numbers of words used in successive sessions, the 3-man groups deviated from that regular trend. We are not inclined to attribute much practical significance to this interaction.

Mean message lengths also varied significantly on successive Days of test, but the data do not show a monotonic trend and the overall size of the effect is relatively small. The largest single effect contributing to the significant Communication Modes by Days interaction is the increase in mean message length between the first and second session in the teletype mode. In the first session, messages in the teletype mode were much shorter (about 4 words, or 33%, shorter) than those in the other two modes. In the second session, message lengths were about one word (12%) shorter in the teletype mode than in the other two modes, but in the third session, message lengths were almost identical in all three modes. It is likely that in their first session in the teletype mode subjects used shorter messages because of their unfamiliarity with the equipment.

The statistically significant effect among the mean relative variabilities ($0{\cdot}01 < p < 0{\cdot}025$) for numbers of messages as a function of sessions shows a tendency for individual conferees to share somewhat more evenly in the production of messages during Sessions 2 and 3 ($\bar{V} = 13{\cdot}0$ and $13{\cdot}6$) than during Session 1 ($\bar{V} = 16{\cdot}0$).

5.2.4. *Problem effects.* The problems were designed to be as much alike as possible and it appears that we were largely successful in meeting that goal. Differences among problems were statistically significant for only two of the seven dependent verbal measures, and there was only one statistically significant interaction involving problems. Because all of the mean differences underlying these significances are small compared to the differences discussed so far, and because the problems served primarily as vehicles for communication, these problem effects do not warrant any further discussion.

5.3. *Equivalence of solutions*

Correlations between the consensus ranked solutions arrived at by each group and the criterion rankings ranged from 0·38 to 0·96. These extreme values both occurred for solutions to the University Budget Problem. The magnitudes of these correlations, or their corresponding z's, are not of much interest in themselves. What is of interest is their consistency or equivalence. For example, if the 2-, 3-, or 4-man groups all arrived at very nearly the same kinds of solutions, or rank orderings, the average correlations for all three sizes of group should be about the same. On the other hand, if smaller groups tended to arrive at different solutions than those reached by larger groups, the mean correlations for the several sizes of group should differ. The same kind of reasoning applies to the other variables of interest in this study.

The analysis of variance of the z-transformed correlations yielded only one significant effect, that due to Problems. On the average, group solutions to the National Issues Problem correlated lower with the criterion rankings (0·79) than did solutions to the University Budget and Student Activities Problems (0·87 and 0·88, respectively). The orthogonal comparison of the University Budget and Student Activities Problem *vs.* the National Issues Problem was significant at $0{\cdot}001 < p < 0{\cdot}005$ and accounted for 98 percent of the variance among problems. The orthogonal comparison between the solutions to the two university-related problems was not significant. In short, teams of students were able to arrive at more consistent solutions to the two problems that would appear to be more directly related to their immediate interests and campus experiences than they were to a problem involving national goals for which they might have been expected to have wider differences of opinion.

Even more important than the significant effects are those that were not significant. Correlations were not affected by Group Size, Communication Mode, the interaction between Group Size and Communication Mode, or successive Days of test. The F's for the first three of these were 1.0 or less.

The coefficients of concordance measured directly the amount of the agreement among the solutions arrived at by the three groups in each of the 27 combinations of group size, mode, and problem. These coefficients ranged from 0·53 to 0·95. There were no demonstrable differences in these coefficients among the three sizes of group, or among communication modes. There was, however, more consistency among the solutions reached for the University Budget and Student Activities Problem than for the National Issues Problem. The analysis of the coefficients of correlation between (1) the mean consensus rankings of the three groups in each of the same 27 combinations, and (2) the appropriate criterion rankings yielded nothing that even approached statistical significance.

Although the three kinds of statistical analysis are different in concept, they are almost perfectly unanimous in their outcomes. Contrary to what we had been led to expect from earlier work (for example, Holloman and Hendrick 1971, Kelley and Thibaut 1954, and Lorge *et al.* 1958) there is here no evidence whatsoever that larger groups produced any different solutions than smaller groups. Nor is there any evidence here that solutions differed when subjects conferred in different modes. Solutions did, however, differ for the three problems. For our purposes, that is a minor finding and serves only to reassure us that our statistical techniques were sensitive enough to detect differences if they existed.

5.4. *Questionnaire data*

Many questionnaire items were open-ended and elicited responses consisting of short phrases or sentences. Even when a question could be answered with a simple 'yes' or 'no,' amplifying comments were always solicited and sometimes made. For these reasons, the questionnaire data are largely qualitative and do not lend themselves to succinct generalization. The thesis on which this paper is based (Krueger 1977) contains frequency counts of most kinds of responses plus extensive quotations from the subjects' comments. What follows here is a highly condensed summarization of a few of the more important points that emerged from the questionnaire data.

1. The face-to-face mode was generally described with words such as informal, personal, relaxed, and spontaneous. Subjects added that this mode allowed them to pick up information from facial expressions, gestures, and tone of voice, and that this mode allowed for a rapid and effective interchange of ideas, the easy formation of compromise, and the development of a spirit of cooperation. Perhaps the most important single constraining factor noted by subjects in this mode of communication was the presence of a microphone which seemed to inhibit some persons.

2. The televoice mode was generally described with such adjectives as quick, fast, efficient, effortless, fun, and relaxing. Several subjects commented that since they could not see their fellow conferees they had to pay more attention to what was being said, and that they were, in fact, able to pay more attention to the problem and less to their partners. The televoice mode seemed to provide enough detachment to prompt five subjects to comment on it spontaneously. Although 19 of the 27 subjects who used this mode did not feel that being able to see their partners would have made it easier for them to arrive at a solution, subjects did comment that this mode of communication reduced the number of supplementary cues they received about the affective

components of communications. One of the principal mechanical difficulties encountered in using the televoice system was the difficulty that subjects in larger groups often had in identifying who was speaking.

3. The teletypewriter mode was generally described with such adjectives as new, interesting, challenging, fun, clear, concise, logical, direct, businesslike, and to the point. Subjects liked this mode of communication because it contributed to an orderly transmission of messages, produced a hard copy record, and eliminated some of the emotionality that would otherwise have occurred in the discussions. The principal disadvantages of the system were the length of time it took people to communicate, the inability of subjects to express themselves fully and adequately in this mode, and their general lack of skill in using a keyboard. Subjects were almost evenly split in their opinions about whether it was a serious disadvantage not to be able to see their partners (14 said "no," 13 said "yes"). They were almost as evenly split in their opinions about whether they would have been able to arrive at a decision more easily if they could have seen each other (13 said "no," 11 said "yes," and 3 gave qualified "yes" and "no" answers).

4. No particularly impressive findings emerged from the several questions concerned with group size. Most subjects (75 of the 81) liked working on a conference team of the size they had. Most subjects thought that solutions could be reached more quickly the smaller the size of the group, thus disagreeing with our objective data, but they also cited as an advantage the increased diversity of opinions that they felt would come from larger groups.

5. Almost all (73 of the 81) subjects felt that their team improved its communication skills on successive days. The improvements they perceived fell into two principal categories: (a) the evolution of a technique, or strategy for solving the problems, and (b) mechanical improvements in communication procedures, *e.g.*, the development of shorthand codes and abbreviations, and improvements in typing skills.

6. Implications

One important outcome of this study is the demonstration that three and four persons can have a face-to-face conference, or a teleconference by voice or by teletype, just about as effectively as two persons can. There was no increase in the time required to arrive at solutions, nor did solutions change demonstrably, as conference groups increased from two to four. These findings about group size are extremely robust. They hold for all three conference modes, all three problems, all three days of test, and all combinations of these variables that were tested in this experiment.

Although larger conferences do not take longer than shorter ones, there is clearly an increase in verbal information load in the larger conferences. Group size had a significant effect on four measures of verbal productivity, number of messages, number of words, messages per minute, and words per minute, that are related to information load. The number of interruptions and simultaneous conversations also increased greatly as groups became larger. When verbal productivity was measured by the average productivity per person, however, differences attributable to group size were no longer significant. Each addition of another conferee to a group resulted in a relatively constant increase in the number of messages and of words. That does not mean that the communicative output was shared equally among conferees. As group size increased, some persons produced relatively more, others relatively fewer, words and messages.

The several conference modes had distinct advantages and disadvantages. Subjects in the televoice mode felt that not being able to see their fellow conferees deprived them of some supplementary cues they would normally receive about the affective components of communication. That subjective impression notwithstanding, televoice conferences were not only significantly faster than face-to-face conferences, but they were also more succinct on all measures of verbal productivity. Subjects in the televoice mode also interrupted each other less frequently than did those in face-to-face conferences, and subjects commented that in the televoice mode they were able to pay more attention to the problem at hand and less to their partners. In short, the absence of gestural and paralanguage cues had no detrimental effect that we could observe.

Although subjects liked the teletype mode because they thought it was logical, businesslike, and to the point, they complained about their lack of skill in typing and about the length of time it took them to communicate in this mode. Conferences by teletype did, in fact, take much longer, but they were also much less wordy than face-to-face conferences or teleconferences by voice. There is also evidence here that the teletype mode is more egalitarian, that is, that subjects in this mode tend to share more evenly in the communication exchanges. The effects attributable to communication mode are extremely robust and hold almost without exception, for all three problems, all three group sizes, all three days, and all combinations of these variables tested in this study.

Despite these differences among modes, perhaps the most important finding for teleconferencing is that there are no demonstrable differences among solutions arrived at by subjects in any of the modes. Almost as important is the finding that learning effects over three days are relatively small, or non-existent. Subjects were somewhat more parsimonious in their use of messages and words on successive days and there is some evidence that subjects in the teletype mode became more adept in the use of the equipment from day to day. Aside from that, performance in these various communication modes was fairly stable over time.

Although this is, so far as we know, the first experiment to have systematically compared the performance of groups of different size in conferencing and teleconferencing tasks, the study obviously has some limitations. Most important, of course, is that four conferees is still a very small number. It seems intuitively obvious that verbal productivity cannot continue to increase linearly as the number of conferees increases. The exact nature of that function, and it must be some sort of curvilinear function, still remains to be determined. In addition, although our two teleconference modes worked well with up to four conferees, it seems unlikely that they would continue to be as effective as the number of conferees increased further. In the televoice mode conferees in the larger groups sometimes had difficulty identifying who was speaking. That difficulty, although not serious with four conferees, has created serious problems in larger voice conferences (Short *et al.* 1976). What would happen in teletype conferences as the number of conferees increased beyond four has still to be determined.

Meanwhile, the findings of this study suggest that for small conferences, televoice and teletype may provide effective and satisfactory alternatives to face-to-face conferencing. Since the equipment and facilities for conferencing by voice and teletype are relatively cheap and available, using such teleconferencing systems as substitutes for travel could have significant societal benefits in these days of ever-escalating fuel costs.

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Vingt-sept groupes divisés en 9 groupes formés de 2, de 3 ou de 4 étudiants ont discuté de divers sujets, soit en face-à-face, soit dans une des deux modalités de téléconférence: le télétype et le télévoix. Chaque groupe n'utilisait qu'une des trois modalités pour résoudre un problème différent au cours de trois jours successifs. Chaque problème favorisait la confrontation des opinions et amenait le groupe à dégager un certain consensus à l'issue des discussions de certains problèmes. La dimension du groupe n'avait pas d'effet sur le temps de résolution, ni sur les solutions elles mêmes, mais un accroissement de la dimension du groupe amenait un accroissement de presque toute les variables de communication dans le groupe. Le plus grand groupe utilisait plus de messages, plus de mots; ils communiquaient plus rapidement et présentèrent une variabilité relative plus importante dans le nombre de messages émis par les individus dans le groupe. Des solutions équivalentes ont été proposés dans les trois modalités de communication, mais les sujets, dans les communications face-à-face, utilisaient plus de messages et de mots que les sujets dans les deux autres modalités. Les vitesses des communications étaient plus élévées et les solutions étaient atteintes plus rapidement dans les situations qui utilisaient les modalités vocales, c'est-à-dire le face-à-face et le télévoix. Il n'y avait qu'un faible effet d'apprentissage.

Neun Gruppen von jeweils 2, 3 und 4 Studenten, 27 Gruppen insgesamt, diskutierten Themen unmittelbar an einem Tisch oder in einer von zwei Telekonferenzen: fernschriftlich und fernmündlich. Jede Gruppe wendete lediglich eine von den drei Kommunikationsarten an, um an jeden von 3 aufeinanderfolgenden Tagen ein schwieriges Problem zu lösen. Jedes Problem förderte eine engagierte Diskussion wobei die Gruppe über bestimmte Problemthemen einen Konsens erreichen mußte. Die Gruppengröße hatte keinen Einfluß auf die Lösungszeit oder auf die Lösung selbst, doch ein Anwachsen der Gruppengröße lief beinahe in jeder Gruppe auf eine Zunahme des Kommunikationsausmaßes hinaus. Die großeren Gruppen verwendeten mehr Nachrichten, mehr Worte, komunizierten straffer und zeigten größere relative Variabilität in der vom einzelnen Gruppenmitglied erzeugten Nachrichtenanzahl als die kleineren Gruppen. Zwar wurden gleichwertige Lösungen durch alle Kommunicationsarten erreicht, jedoch benötigten die Mitglieder der Konferenz an einem Tisch mehr Nachrichten und Worte als die Teilnehmer beider Telekommunikationsarten. Bei den zwei Konferenzarten, die einen mündlichen Nachrichtenkanal hatten, d.h. unmittelbar an einem Tisch und fernmündlich, war die Kommunikationsgeschwindigkeit viel höher und Lösungen wurden viel schneller gefunden als bei der fernschriftlichen Art. Nur wenige Anwendungeinflüsse wurden gefunden.

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